REPORT

OF BOARD OF ENGINEERS

—ON—

New Orleans Harbor,

APRIL 8th, 1878.

G. WEITZEL,
W. H. H. BENYAURD,
C. W. HOWELL,
B. M. HARROD.
J. A. D'HEMECOURT.

ROB'T C. WOOD, Secretary.

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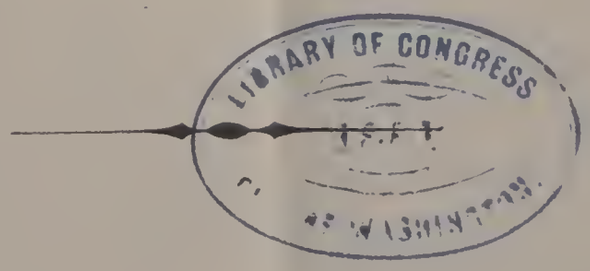

NEW ORLEANS:

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REPORT.

At the regular meeting of the City Council of New Orleans, on October 16, 1877, Hon. Chas. Cavanac, Administrator of Commerce, presented the following resolution :

Resolved, That the Mayor be and is hereby authorized and directed to cause an accurate survey and sounding of the river to be made from Morgan's Landing to the lower limits of the Third District, in order to determine the character and location of channel, the velocity of current, the depth of water, the nature of the banks and such other data as will be necessary in effecting the permanent relief proposed.

In compliance with this resolution, which was unanimously adopted, Hon. E. Pilsbury, Mayor, proceeded to the formation of a Board of Engineers.

Invitations were extended to Genl. G. Weitzel, Major W. H. H. Benyaurd and Major C. W. Howell of the U. S. Corps of Engineers, and to Mr. B. M. Harrod, Chief Engineer of the State of Louisiana, and with these gentlemen was associated Mr. J. A. d'Hemecourt, City Surveyor.

The Board thus composed convened in New Orleans, on the morning of November 17, 1877, and after organizing, addressed the following communication to the Mayor :

BOARD OF ENGINEERS,
New Orleans, La., Nov. 17th, 1877.

HON. ED. PILSBURY, *Mayor City of New Orleans :*

Sir—The Board of Engineers convened to consider questions relating to protection of the City front, is now in session and would be pleased to receive from you a detailed statement of your views as to the duty required of them.

It is desirable to have explicit instructions as to extent and character of the investigation you desire and as to points to be covered by report.

Very respectfully,
Your obedient servant,
G. WEITZEL.

To this communication the following reply was received:

STATE OF LOUISIANA,
MAYORALTY OF NEW ORLEANS,
City Hall, Nov. 17th, 1877.

MAJOR GENERAL G. WEITZEL, *U. S. Engineers:*

Sir—In reply to yours of even date, I have the honor to submit the following points, which appear to me desirable in connection with your presence as a Board of U. S. Engineers.

1st. A thorough and complete survey of the river and its banks from the upper to the lower limit of the City, giving cross sections of the stream every half mile, and the direction of the current.

2d. A plan for the temporary preservation of the banks and wharves from destruction, to apply only to the most exposed points, and adapted to the present resources of the city, which are limited, accompanied by estimates.

3d. A more general and comprehensive plan, embracing the river front of the Second and Third Districts, as a permanent work, with estimates, so as to be commenced and carried on gradually as the future prosperity of the City may admit.

Your obedient servant,

E. PILSBURY,
Mayor.

Letters of invitation were then addressed to distinguished local Engineers and others, requesting them to meet the Board on the 19th inst., and give the members the benefit of their personal experience and opinions.

Four interrogatories were propounded, the responses to which, together with other matter, will be found in the appendix.

The Board remained in session until the 23d inst, engaged in a thorough examination of the harbor, study of data, plans, etc. On this day the following preliminary report was rendered:

NEW ORLEANS, Nov. 23, 1877.

Hon. ED. PILSBURY, *Mayor:*

Sir—I have the honor of submitting a preliminary report of the Board of Engineers convened here by invitation of the City Government.

Permission to accept the invitation on the part of Major

Benyaurd and myself was conditioned upon a non-interference with our duties as public officers. Our presence in our respective Districts at the end of this month is necessary.

Full arrangements have been made for the continuance of the work during our absence, and the resident members of the Board have been directed to confer with your Honor in all matters pertaining to it.

Upon the completion of the Hydrographic Survey, which is essential to the objects we have in view, Major Benyaurd and I will return to New Orleans, in order that final action and report of the Board may not be delayed.

I respectfully suggest that your Honor place at the service of the resident members of the Board competent and reliable divers to make such examinations as may be deemed necessary to the prosecution of their labors.

Very Respectfully,
Your Ob't Servant,
G. WEITZEL.

NEW ORLEANS, Nov. 23, 1878.

HON. ED. PILSBURY, *Mayor, City of New Orleans:*

Sir—The Board of Engineers convened at the request of the City Council "to examine and report upon the means necessary to protect the harbor of New Orleans, from the incursions of the river," has the honor to submit the following preliminary report.

While the Board has been able, from study of the data at its command, to decide upon the general features of a plan for the permanent protection of the whole City front and its wharves, it is thought advisable to await completion of the careful hydrographic survey called for by your Honor in your letter of instruction of the 17th inst., before presenting a detailed plan and estimates for the protection of the whole front.

We desire simply to present at this time our views as to what may be done at the most important points, and outline a general plan, the details of which, together with estimates, will be given in a report to be made after results of the survey for which you have provided may be made available.

The Board has made a careful examination into the condition of affairs existing along the City front; has examined the valuable charts and reports placed at its disposal by the State and

City Engineers, and has obtained in writing and conversation the opinions of distinguished local engineers and other gentlemen, whose professional or other interest in the questions presented to the Board, has led them to pay attention to the matter of river front protection.

All this information will be submitted with our final report.

The general plan of protection that in the opinion of the Board offers the most certain result, and besides appears the most economical, is one that for two centuries or more has been successfully followed for the protection of caving banks and abraded sea shores in Europe, especially in Holland and Germany. It has been for many years also successfully applied by American engineers on the Northern lakes, in the Missouri river, and on the Mississippi river above Cairo.

The method consists in the protection from scour by currents and eddies, of the unstable strata exposed in the sloping portions of the river bed, which by being washed out permits portions of the banks to drop down or slide into the river, thus frequently causing great loss of property.

The method is that of revetment, and its details have depended in a large measure on the character of the material suitable for the purpose and most easily and cheaply obtained and applied.

Where there is an abundance of small growth timber, such as is found in great quantity in the swamps of Louisiana, along the banks of the Mississippi and the higher portion of the river battures, this has been generally used, and in great variety of shapes of hurdles, mats, mattresses, fascines, rough bundles and even thrown in loose ballasted with natural or artificial stone, or secured to the caving slope by piling or by stakes.

A variety of other material that may be converted into the shapes above named has also been used, such as the longer, coarser grasses, reeds, straw, bagasse, etc.

The Board is confident that this system of revetment judiciously applied all along the exposed portion of the City front may be made to effectually protect it, and at a reasonable expense, but owing to changes that have occurred since the date of the latest survey available, the details of construction of revetment, which must be varied to suit the local peculiarities and the distance to which revetment must at points be carried from the shore line, can only be fully decided upon after the de-

tailed survey, for which you have provided, shall have been completed. As a consequence, estimate must also be postponed until that time.

The Board has been presented with the most exact data as to the cost of various revetment works of the character suggested, and hope to be able soon to offer a close estimate for that recommended in this case.

In the meantime, however, there are two points along the City front at which works designed for protection are now in progress, which seem to call for the immediate action of the Board.

The cave in the 3d District, opposite the Atlantic Cotton Press, is one of the points. At this place the river has encroached upon the land so that at this time the shore line is found where it was 35 or 40 years ago, having washed away about one hundred (100) feet of ground formed by it in front of the levee since that time.

It is possible that this cave has reached its limit, as it did then. The shore line may again begin to build out into the river; but as a wise measure of precaution, it is deemed advisable to continue the work of protection now in progress under the direction of the City Surveyor, with modification to meet the general views of the Board.

It is evident that the defective strata, from which there is the most trouble to be apprehended, lie between the shore line and the front line of the wharves.

It is therefore recommended that the single line timber bulkhead be completed, and the slope in front carpeted with hurdles or fascine mats or bundles of brush made into rafts and sunk upon the bottom with ballast stone for a sufficient distance out to cover these strata and protect them from further scour.

The Board does not wish to hamper the engineer in charge by specifying details, since in the course of construction his frequent soundings may indicate cause for change in minor details. He has been requested to submit a project for the work under the general plan suggested, and with it present estimates.

The cave at the head of Soraparu street is but a short one, occupying the space between two wharves.

From the report of Mr. M. W. Francis, the diver who examined the slope at this point, it appears that the defective

stratum lies at a depth of 25 feet, and that it is from 10 to 15 feet in thickness, its upper edge slightly overhanging. At a depth of about 70 feet, which lies outside the line of wharf front, he found a very stable stratum.

At this point the same measures are recommended as at the cave in the 3d District; the hurdle mat or fascine revetment to extend from the bulkhead out to the depth of 70 feet, unless examination should indicate it, may not be necessary to revet so far out.

The City Surveyor has been requested to also submit project and estimate for this work.

The resident members of the Board have been requested to confer with your Honor as to direction, character and extent of survey, and in every way represent the Board during its recess.

All of which is respectfully submitted.

G. WEITZEL,
W. H. H. BENYAURD,
C. W. HOWELL,
B. M. HARROD,
J. A. D'HEMECOURT.

ROBT. C. WOOD, *Secretary.*

General Weitzel and Major Benyaurd being compelled to return to their respective stations, the three resident members of the Board were charged with the supervision and execution of the work of survey, etc., necessary to the final plans and report of the Board.

From November 23d, 1877, to April 2d, 1878, when the full Board reconvened, the various works of survey, sounding, etc., were vigorously prosecuted under the immediate charge of Engineers selected for that purpose.

From April 2d to April 8th, the Board was engaged in the examination of maps, plans, charts, etc., and on the latter day presented the following report.

NEW ORLEANS, April 8, 1878.

Hon. ED. PILSBURY, *Mayor of New Orleans:*

Sir—The Board of Engineers, convened at the request of the City Council "to examine and report upon the means necessary to protect the wharves and harbor from the incursions of the river," beg to submit the following:

Referring to your letter of November 17, 1877, the engineering information requested of the Board was as follows:

1. A thorough and complete survey of the river and its bank from the upper to the lower limit of the city, giving cross sections of the stream every half mile and the direction of the current.

2. A plan for the temporary preservation of the banks and wharves from destruction—to apply only to the most exposed points, and adapted to the present resources of the city—which are limited, accompanied by estimates.

3. A more general and comprehensive plan, embracing the river front of the Second and Third Districts, as a permanent work, with estimates, so as to be commenced and carried on gradually, as the future prosperity of the city may admit.

At a former session of the board, held in November last, a preliminary report was rendered your Honor, respecting the condition of affairs along the city front. In this the means necessary to be taken to preserve the most exposed points (which were at the foot of Sorapuru street, and at the foot of Montegut street,) were presented, and the execution of the plans were entrusted to and carried out under the direction of the City Surveyor. A general plan also was outlined, which was to embrace the entire city from Carrollton to a point below the United States Barracks, or so much of it at least as needed permanent protection. The board was unprepared at that time to decide upon all the details to be observed in this permanent plan of protection, owing to the lack of the necessary information respecting the condition of the caving banks, their extent, their composition, slope, depth of water, etc., all of which could only be furnished by an exhaustive and extensive survey such as called for by your letter.

This survey was undertaken under the personal supervision of the local members of the board, with aid furnished by the government and by the city, and was carried to a successful termination. It is complete and thorough in all the details necessary for a proper study of the problem submitted to the board. It extended from a point above Carrollton to a point below the Barracks, embracing also the right bank of the river, and was made in three sections.

Section 1 started from a point some 3300 feet above the Metairie road, at the upper end of a plank revetment, where

there is a wide batture, and followed the left bank to the Orleans Park, where there is also a wide batture, a total distance of 22,243 feet. At intervals of 100 feet lines of soundings were made, extending out from 300 to 400 feet, and where there were caving banks intermediate lines were sounded. Thirty-four sections were also sounded across the river in this stretch, and from 100 to 120 soundings were located on each section. Thirty of these cross sections were nearly at the same points as those made in the survey of 1851 by Capt. (now General) Humphreys.

From the Orleans Park to Canal street, there being no caving of the left bank, no survey of that line was made.

Section 2 commenced at Canal street, and the shore line was run from that point to the Slaughter-House, a distance of 21,800 feet. On this stretch soundings were made at each 100 feet as before, extending out into the river from 300 to 400 feet. Twenty cross sections were also sounded at nearly equal intervals, but only about eighty soundings were located on each one.

Section 3 included the right bank of the river, and commenced at a point 3450 feet above the lock at Westwego, and extended down to the point at Algiers, and is some 47,000 feet in length. Soundings were made at intervals as in the surveys of the other sections, and 19 cross sections were sounded across the river between the lower end of the Carrollton section and Canal street, thus filling that interval.

Gauges were kept at Carrollton, Canal street, the Mint, and at the United States Barracks, and all soundings were reduced to the same plane of reference as that of the Delta survey, and reads on the Carrollton gauge, 15.70.

The condition of the banks as developed by the survey, is as follows: From the upper end of the Carrollton survey to station 186, there is a wide batture and no caving going on at present; from station 186 to station 91 (at head of Carrollton Avenue), there is more or less caving of the bank throughout the whole distance. Between stations 140 and 157 some 500 feet of the bank have caved in since 1858, and at the Carrollton Hotel, which is at the lower end of the present cutting, in that time some 200 feet have gone in. The total length of the caving in this section is 9200 feet.

From station 91 down to station 55 there have been about 200 feet caved in since 1858, but there is little, if any, caving

going on now, except in two places—one about 300 and the other about 200 feet long. Below station 55, there is a fill at present and a wide batture.

Below Canal street from Morgan's wharf, at station 10 to station 160, a distance of 15,000 feet, the bank needs more or less protection. It has, however, only been deemed advisable to apply protective measures to the slope of the bank from Morgan's wharf to Congress street, a distance of 7500 feet, leaving the remaining portion of the city below that point to be protected by a new levee.

On the right bank the space through which the caving takes place extends from station 49 to 176, below the locks, and from station 296 to 476 above and at Algiers, a total length of 31,700 feet. The board, however, does not deem it at present absolutely necessary to apply the works of protection to this entire stretch of bank, but only to a portion embracing Nine-Mile Point. The locations of the different caving banks at which it is proposed to apply the works of protection can better be understood by reference to the sketch map accompanying the report, while at the same time an inspection of the index and detailed maps will give all the information respecting the depths of water, slope of bank, composition of same, etc., much more fully than can be indicated or enumerated in the report.

The results of the survey of the banks show that they are composed of a hard blue mud, with intermediate soft strata. These soft strata outcrop at varying depths, as shown on adjacent lines of soundings. In some cases they are quite regular, in others quite irregular, as if deposited upon a slope. The cavings result from the saturation of these layers of soft material, which are afterwards washed or cut out, causing the superincumbent mass to fall or slide into the river. This caving takes place mostly upon a falling river, the high water seeming to act by its pressure in sustaining the bank. These soft strata occur at various depths from near the surface to near the bottom of the river, and the greater or lesser amount of cave seems to depend upon their relative position.

In order, then, to retain the bank in its natural position, the remedy to be applied would seem to be some method by which the cutting out of the defective strata could be prevented. This is best subserved by applying to the bank a revetment extend-

ing so as to cover the whole slope, or so much of it as is likely to be affected. The banks along the city front present conditions not unfavorable to the successful application of a project, such as was outlined in our preliminary report of November last. The general method indicated there was to cover the slope of the bank with a revetment of brush and stone in such shapes and forms as best suited the particular locality where it was to be applied.

While much more costly applications of timber and stone might subserve the object in view, those of brush and stone in the shape of matting applied to the banks have the merit, that while suitable for the purpose, they are comparatively cheap, are durable, are easily applied, and on account of their pliability can be well adapted to the irregular slopes of the banks caused by the caving. At the same time the carpeting of the bank in such a manner causes no undue contraction of the water way, and allows the current to move along in its natural course.

At the upper section of the river at Carrollton, and on the right bank above Algiers, where there are no wharves, it is proposed, in accordance with the above views, to cover the slopes from a short distance above low water to a distance out such that all defective strata will be protected by a layer of brush formed into rafts and ballasted with stone sufficient to keep them in position.

Along the section of the river from Morgan's wharf to the foot of Congress street, it is proposed to form a bulkhead extending the entire distance in a line with the outer row of wharf piles, by driving piles in pairs, the distance between the centres of each pair being six feet, and between the piles of each pair three feet. These piles are bolted together at low water and at the top. Between the piles and extending up and down stream, brush facines are piled up to low water mark, forming, so to speak, a brush wall. Above low water mark on the outside of the piles, plank are placed extending to high water mark. From the foot of this row of piles, extending out as far as may be necessary, to cover all defective strata, a layer of brush and stone in suitable form is laid upon the slope. The object in not continuing the revetment clear up to the banks, as in the other districts, is that it has been found from experience that great difficulty and expense will attend the removal of the great num-

ber of piles and timber work now forming the wharves and occupying a portion of the slope needing protection, and which it would be necessary to remove were it determined to carpet the entire slope, adding considerably to the expense and more than circumstances would warrant.

Statistics at the disposal of the Board indicate that the largest interests involved are in section 2, from Morgan's wharf to Congress street. It therefore seems expedient that the proposed measures of protection should first be applied to that part of the shore. Similar reasons indicate that the work on the Carrollton section, No. 1, should be next done, and, finally, that work above the Nine-Mile Point, on the right bank, which is essential as a protection to works in section 1 and the shore below.

The following are the estimates for the protection of so much of the city front as the Board deems absolutely essential at the present time to the preservation of the wharves and harbor, though eventually the protection of the entire front may have to be undertaken. These estimates being approximations, the board has sought to make them sufficiently large to cover all contingencies, leaving to the engineer who may have charge of the construction of the work a certain latitude, whereby such changes as may appear necessary, and as circumstances call for, can be made as the work progresses.

ESTIMATES.

Section 2, from Morgan's wharf to Congress street—		
Piles and planking at $6 33 per running foot..	$47,475	
Filling between piles, 6600 cords, at $2 50 per cord.....	16,500	
Brush matting, 7500 feet long, 200 feet wide, in position and ballasted	146,025	
	$210,000	
Contingencies.....	25,000	
		$235,000
Section 1, at Carrollton—		
Brush matting, 9200 feet long, 200 feet wide, sunk and ballasted, at $19 50 per running foot $179,600		
Contingencies	18,600	
		198,000

Section 3, Nine-mile Point—		
Brush matting, 2000 feet long, 200 feet wide, sunk and ballasted, at $19 50 per running foot	$29,000	
Contingencies	4,000	
		43,000
Total estimated cost		$476,000

Herewith are transmitted the drawings pertaining to the survey, consisting of—

Four index charts.

One sketch map, showing locations of proposed improvements.

Two sectional drawings, showing details of proposed constructions.

Forty-three sheets of drawings, showing details of survey.

There are also transmitted all the papers alluded to in our preliminary report, consisting of letters, views, etc., of professional and other persons, in regard to the work.

The board desire to express their acknowledgement of the valuable services rendered by Commodore C. P. Patterson, chief of U. S. Coast Survey; the officers and crews of the United States men-of-war Enterprise and Canonicus; Messrs. H. C. Collins, W. H. Williams, Geo. d'Hemecourt, M. W. Darton, H. S. Douglas, Eugene Thompson and Capt. M. W. Francis and their assistants.

We would respectfully recommend to your Honor that provision be made for completing the maps, etc., of the survey, and the careful preservation of same as a valuable contribution to the hydrography of the river in the vicinity of New Orleans.

All of which is respectfully submitted.

G. Weitzel,
W. H. H. Benyaurd,
C. W. Howell,
B. M. Harrod,
J. A. d'Hemecourt.

Robert C. Wood, Secretary.

On April 9th, the Board, after having arranged for the completion of maps and publication of the report, adjourned *sine die.*

Rob't C. Wood,
Secretary.

APPENDIX.

The following are the four interrogatories submitted by the Board of Engineers to those who were invited to present their views.

1st. What is your opinion as to the cause of caving of the river bank and destruction of wharves at various points along the river front?

2d. What have you observed as to effects of caving and of the phenomena attending?

3d. What would you suggest as a temporary and cheap method of preventing caving or retarding it?

4th. What would you suggest as a permanent measure?

In response to the above the following communications were received:

[WM. H. WILLIAMS.]

NEW ORLEANS, LA.,
Seventh District, late Carrollton,
Nov. 20, 1877.

To Messrs. WEITZEL, BENYAURD AND HOWELL,

U. S. Engineers, etc:

Gentlemen—In compliance with your request, I offer you the following answers to the several questions you have submitted:

Question 1st. As to the cause of caving in the Mississippi River banks and the destruction of the wharves in front of the City.

Answer. My opinion is that caves are caused by the saturation and washing out of beds of quicksand lying at a depth under the banks.

The alluvial regions, I think, are underlaid by such beds,—lying not in continuous strata, but rather in the form of fields and veins. These extend out in localities to the bed of the river, and by the action of violent currents, are washed *into* and in time washed *out*, a cavity being thus formed, into which the bank above falls.

The first fall of the caving bank is mostly perpendicular; but this is followed by a sliding out movement, by which the falling ground, in immense quantities, is carried out some distance into the bed of the river.

Such quicksand beds may be undisturbed for years, as no

caving takes place until they are reached by some accident in the movement of the undermining current.

The undermining current is strongest in the apex of a bend of the river, or within some limited distance below.

The wharves in the Second and Third Districts, being in and below the bend, are so situated as to be constantly exposed to the strong attack of the current from and around the Algiers point.

The quicksand beds lie at various depths below the surface, from 15 feet to perhaps the depth of the bottom of the river. Those which cause the greatest caves, I am inclined to think, lie the deepest, and those perhaps so deep that they cannot be reached by any piling or other work that might be constructed to prevent caving.

This may be the case at the wharves in the Second and Third Districts. There may be undermining here at a depth of from 50 to 100 feet below the surface, and there is nothing in the timber structure of the wharves that could prevent it. This would account for any perpendicular caving of the wharves, such as has occured from time to time.

The mere falling in of the front timber-work of the wharves, or of the bulkhead jetties in the Third District, can be accounted for by the mere abrasion of the river bed, taking place outside of the works, and continuing until the hold of the piling is destroyed.

Question 2d. As to the effects and phenomena of caves as known from my own observations.

Answer. I have to say that my experience and work have been chiefly in the sections of the river from New Orleans up to Donaldsonville, and down to the Forts. Within that range, I have had much observation, and from this observation I make the following statements, though it must be said that the facts are all old, and the same as known to all other observers.

Caves occur in the deep bends of the river, or within a certain limited distance below, and where the current strikes violently from the opposite point. This is the case in the Second and Third Districts and at Carrollton.

Caves usually occur after the fall of the river and very seldom during high water. The lateral and perhaps the upward pressure of the water helps to sustain the bank.

Two caves seldom take place at the same point, within the same year, or within several years. This seems to be a confirmation of the sand-bed theory. The earth thrown down in the first cave would cover the entrance to the quicksand bed, and no further caving would take place, until this deposit is washed away by gradual abrasion.

There is, in caving, what may be called *deep* caving and *shallow* caving: deep caving, in which the fallen earth sinks entirely out of sight and is lost in the depth of the water; and shallow caving, in which the bank sinks perpendicularly for but a few feet and then rests, sometimes for a number of years.

Caving often travels down stream in a series of years. Every bend in the river has an opposite point. This point often wears off to some extent, and the attack of the current passing around it, is thrown further down on the caving side. This is the case at Carrollton, where the opposite point has considerably worn off. But I believe it is no the case in the Third District, as the Algiers point has been kept up and not allowed to wear off.

A cave is not a lateral breaking and a lateral tumbling of the bank, but *first* a perpendicular fall and *then* a sliding out.

Question 3d. As to a "cheap temporary mode of preventing or retarding caving."

Answer. I must say that I have little confidence in the success of any attempt that can be made for the purpose.

Mere abrasion either on the side of the bank, or even on the side of the bed of the river, can be prevented by revetting the bank, or by means of solid bulkheads set out from the bank. But these are no protection against undermining in the bed of the river, outside of the lines on which these works stand; and they are therefore no safeguard against caving.

So far as the situation in the Third District is concerned, it may be that some works can be constructed there which will be useful against abrasions, though of no use against caving. But of this we are perhaps not sufficiently acquainted with the facts to have a definite opinion; yet I venture the following thoughts.

Much depends upon whether the difficulty in the Third District has been caused by actual caving, or by mere abrasion. If a thorough investigation shows that the bulkheads have fallen only from abrasion on the river bed outside, it seems to me that the exposed banks could be protected again by rebuilding a close bulkhead nearer the shore.

If there has been actual caving, the situation is more difficult. Yet even then it still seems to me that for immediate protection, the close bulkhead might be built as the proper measure, if a foundation is found for the work to stand on. For immediate protection, either the bulkhead may have to be built or a new levee constructed. Yet the bulkhead would be of no use except as a temporary safeguard, and that only against abrasion of the bank, and not against caving.

Question 4th. As to "what permanent measure I would suggest for preventing caving."

Answer. I would answer that I have no favorite plan to suggest, and I have little confidence in any I have heard proposed by others.

The task required is to prevent the undermining currents from acting on the exposed veins and beds of quicksand. No revetment or bulkhead, or no work of any construction, either of wood or iron, could be of any value for this purpose, unless it could reach below the level of the lowest sand beds, which are to be guarded against; and these may be at an unlimited depth, even as low down as the whole depth of the river.

The magnitude of such a work, the difficulty of locating it effectively and the expense involved, would all be so great that the project, it seems to me, could only be regarded as practically impossible.

If anything can be accomplished in the way of warding off the undermining currents from the quicksand beds, I think it is most likely to be effected by a system of timber or iron jetties located in front of a caving bank, and built out as far into the bed of the river as they can be carried out and made to stand.

The effect of these, in throwing the body of the current away from the caving, and at the same time causing some deposit of sediment between jetty and jetty, might or might not be sufficient for the desired purpose.

To be successful, the jetties forming the series, would require to be very numerous, standing close together, all projecting far into the river, and built with the greatest strength.

If they should terminate before reaching deep water, they might not affect the lower currents down to the lowest sandbeds. And if they should stand too far apart, the effect on the one jetty would be lost before the current could reach the next.

Many other particulars would need to be considered, connected with the matters of location, materials and mode of construction; but these are not appropriate to the present stage of your investigations. This project I mention, but without expressing confidence in it.

Please excuse the length of these answers. They are longer than I desired, but the subject is so large that all I have said is but a skeleton of elementary facts and opinions and could not be embraced within a shorter space.

Respectfully submitted,

WM. H. WILLIAMS,
Surveyor and Civil Engineer.

[A. F. WROTNOWSKI.]

NEW ORLEANS, LA., November 21, 1877.

GEN'L GODFREY WEITZEL,
Chairman Board of Engineers, U. S. A.

Sir—I have the honor to acknowledge the receipt of an invitation to be present at a meeting of your Board, also a letter propounding questions relative to matters at issue before your Board, and asking my answers to the same, which I append herewith.

Question 1*st.* "What is your opinion as to the cause of caving of the river bank and destruction of wharves at various points along the river front?"

Answer. The causes of caving, in my opinion, may be enumerated under five different headings, to-wit:

First—By the force of the current striking upon an exposed point, as in a sharp bend.

Second—By the scouring upon a shifting layer of quicksand and undermining the same.

Third—By an over-amount of artificial weight, such as gathering of material, or the abutting of large levees upon others, over an unstable and permeating bank.

Fourth—By submarine obstruction—not being apparent on the surface—disturbing the governing elements of the flow of water.

Fifth—Continual rains making a heavy bank at low water to give way or "slough."

From the position of the caves as appears on the City Map, I ascribe the present caves below the French Market to the first enumeration. That the contours and relative position of the river bank at that point is such as to receive the scouring force of the current, and will do so until the contour of the bank will elongate and appropriate itself to the volume and minimum force of the current.

I am also led to believe that the said caving was somewhat hastened by the wharves built at those points of late years. That the piling for said wharves was not driven sufficiently deep to reach a firm bottom, and was, as it were, only driven to the bed of quicksand, and therefore adding weight, disturbing the strata and hastening the sloughing.

Question 2d. "What have you observed as to the effects of caving and the phenomena attending it?"

Answer. The effect of caving is usually attended by a succession of caves—that is, the first cave, no matter what are its proportions, is sufficient to disturb the regimen of the river, and so cause other caves in the immediate vicinity, and generally above the original cave—for this reason, that where a cave takes place, the material carried into the river is deposited at the base, suddenly forming a barrier to the free flow of water above,—scours the bank and undermines it, hence the caving above. This may however not happen if a sudden and continued rise in the river takes place, such a freshet always transporting a supply of sediment which is deposited in such caves, strengthening its walls and preventing a further sloughing. The increased volume of water carries or scours away the freshly deposited material from the bottom, leaving a free flow, and thus relieves the bank above from an abnormal action.

Question 3d. "What would you suggest as a temporary and cheap method of preventing caving or retarding it?"

Answer. As a temporary method—where a case occurs or is apparently threatened—I suggest the application of willow mattrassing as a revetment, of sufficient length to reach and cover the bottom of the cave, to be laid perpendicularly and properly ballasted. The mattrass to be laid above the cave, of such dimensions and shape (say twenty-five feet wide and two feet thick) as to render it flexible, so as to adapt itself to the shape of the bank, form one common mass with the bank, and

thus break the undermining action of the water. These should be laid about one hundred feet apart, and say for three or four hundred feet along the bank. This method, I believe would be inexpensive and prove effectual.

I would respectfully urge and call your attention as a part preventative to caving—that when new wharves are built, the piling should be driven as far as it will drive—renew driving after a few days, with a heavier hammer, and penetrate by all possible means to firm strata beyond the action of the water—and not until then will the wharves become firm.

Question 4th. "What would you suggest as a permanent measure?"

Answer. As regards this question, I am at a loss to suggest a permanent system, without going beyond the limits of reasonable expenditures. The shiftless Mississippi will not permit such improvements as are made on rock bound streams. I have however seen a few portions of the river bank permanently protected. In one case, in front of the Camelia Plantation, in the Parish of St. John, where about 50 years ago the bank was loosely but rather evenly laid with brick, from an old kiln and sugar-house, mixed with stone ballast, for a distance of something like 400 feet along its front, and to this time stands as firm as a rock. But to apply this method to 13 miles of city front, is questionable whether enough ballast could be obtained without an unwarranted expenditure.

A very cheap material, and which has successfully been used, is the baggass, from sugar-houses. This forms a very good revetment when properly ballasted, but I doubt, even in this, if enough could be obtained.

I am, however, a strong advocate of the willow mattrass method, and, I believe, by a liberal application along the principal exposed points of the city front, some permanency would be secured to the prevention of caving. I think this system worth while trying, and so recommend the same.

I am, very respectfully,

Your obedient servant,

A. F. Wrotnowski,

Civil Engineer.

[HENRY ELLERMANN.]

NEW ORLEANS, Nov. 21, 1877.

TO THE BOARD OF U. S. ENGINEERS:

Gentlemen—I have the honor to reply to your questions: —

First. In my opinion the high and low water we had in 1876, was the cause of the caving of the river bank and destruction of the wharves at various points along the river front; low water, that year, was lower than it had been for thirty years previous. According to my observations it was 16 feet, 2 inches between high and low water.

For thirty years previous to 1876, it was not as low by $1\frac{1}{2}$ to 6 feet.

I recollect that in 1856 there was only a half stage of water, and during that year no caving occurred anywhere in front of the city. In 1876, the depth of the channel, at from three to five hundred feet from the wharves, was probably 140 to 150 feet, and the deposit at high water was very heavy, and at low water this deposit would slide into the river, carrying the wharves with it.

Second. In my opinion, if fewer piles were driven, the better it would be for the river bank. As I stated before the Board of Engineers, in my practice for the last thirty years I have been driving piles 15 to 43 feet into solid ground, and the consequence has been that when the caving occurred, and we had to wreck the old wharves, we found one pile in three broken off in the surface deposit, and the other piles were so split and bent as to be of no service. In my opinion, if heavy timber, say from 18 to 24 inches square, were used, it would cause a greater caving than the timber now employed, but an experiment might be made to test it.

Third. I would suggest, in answer to this question, crib-work for 300 feet or more where the worst cavings have occurred, as an experiment,* and herewith enclose a plan for a cross-section of crib-work, which I will be pleased to explain to the Board. This crib-work to be sunk in water, not deeper than eight feet nor less than five feet, with ballast and fascines. Probably this might succeed in making the levee solid.

Fourth. It is my opinion that if the river had more outlets,

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* The plan is omitted.

such as exists at Bonnét Carre, it would be better for the river banks in front of the city, and I believe that if crevasses had not occurred at Morganza and Bonnet Carre, the Third District would have been inundated by a crevasse there.

In conclusion, I will remark that where the caving or landslides in the Third District have been so great, I suggested to the City Surveyor to build new wharves between the old ones, to prevent the pulling out the old piles, which weakens the bank, and I will instance that at the lower end of the Liverpool wharf, where hundreds of old piles are to be pulled out, no wharf building should be done this year.

I have the honor to be

Very respectfully yours,

HENRY ELLERMANN.

[J. HENRY BEHAN.]

NEW ORLEANS, LA., NOV. 21, 1877.

To GENL. WEITZEL, &c.

Gentlemen of the Hydrographic Commission:

Sirs—In answer to your interrogatories, I respectfully submit the following:

1st and 2d. The caving banks in the 2d and 3d Districts, which are the principal points involved in this issue, is caused by the action of the river current undermining the annual deposit. This deposit, composed of sand, particles of gravel and vegetable matter, with the immense quantity of ballast and debris thrown upon it from the shipping and shore, is held up during high water; when the river commences to fall, the water runs through it like a sieve until it becomes apparently firm, but during this process of transpiration the river has fallen from 8 to 12 feet, and has by the action of the current and the swell caused by passing steamers, also the swell caused by easterly winds in August and September (these winds prevailing at this time of low water) been undermined, and when the wharves become free of shipping the whole mass is precipitated into the river from the inside. This mass becomes disturbed and scattered by the current before it reaches the outer piling, and leaves them standing, with only a slight incline towards the river; the current by its contact with the point on

the opposite shore is accelerated and thrown upon this bend with additional force, which makes it very effectual in its work of destruction. The effect of this caving, as has no doubt been observed by your Honorable Commission in your recent inspection, is threatening this District (3d) at high water, with possibly a crevasse and inundation.

3d and 4th. The nature of the bank along these Districts, from a recent inspection made by myself, have sufficient slope to admit of some practicable plan of *permanent* protection. Any temporary work done has to be renewed from year to year, and instead of being cheap, costs a vast deal more than any permanent work costing originally twice or even four times as much; therefore, I could not, in justice to this community, suggest any temporary plan to your honorable body.

The work being done by the wharf contractors is *temporary enough* and cheap enough for them, but not for the requirements of commerce or to the satisfaction of this community, who have to pay for it.

As for a permanent work I have already submitted to you for your examination, accompanied with a drawing, a plan proposed by myself for protecting this particular location (2d and 3d Districts). There seems to be some fear or antipathy to piling. Why? Because it has always been done in straight lines, following the natural course of the river bank, or by bulkheads two or three hundred feet apart, which have been undermined by the current, while I propose to make the line diagonal, each intersection at obtuse angles, deflecting the current, causing a deposit instead of a wash, thereby adding strength to the work instead of weakening it.

I will add that I am confident from my observations that a work of this nature can be made permanent to protect the river front, with the additional advantage of being able to have, in conjunction with it, permanent and sufficient wharves for the shipping.

Any system of sinking mattresses on a shelving bank, without something to hold them, as designed in my plan, (or some other) will meet with the same fate as the deposit and ballast alluded to before, carrying with it the wharves and improvements every

year, and finally the street and property adjoining. If a levee should be built to protect the street, the mattresses and wharves would have to be renewed annually, a never-ending, interminable and expensive job.

Thanking you for your kind consideration,

I am, gentleman,

Your very obedient servant,

J. HENRY BEHAN.

[JAS. B. EADS.]

PORT EADS, November 20, 1877.

Mr. PAUL A. D'HEMECOURT, Secretary.

Dear Sir—Your letter containing certain questions addressed to me by the Board of Engineers, now sitting in New Orleans, has been forwarded by telegraph from my office in that city.

I have the honor to submit the following answers:—

Question 1st. "What is your opinion as to the cause of the caving of the river banks and destruction of wharves at various points along the river front?"

Answer. I am unable to specify the immediate or local cause of the caving, as your question is accompanied with no information upon the subject.

I have not seen a survey of the river in front of New Orleans within the last two years, and have never examined one with reference to this question.

Caving banks on alluvial streams are chiefly caused by irregularities in the width of the river; these create different rates of current, and consequently induce scour and deposit in the neighborhood where these irregularities exist. When the river is tortuous, a slight caving in the bends will occur from the difference between the velocity of the water moving in them, and that moving around the points; but the destruction of the banks in the bends is so gradual, if the river above be approximately uniform in width, that the caving is scarcely noticeable. The deposit in the opposite points is likewise very slow for the same reason.

Question 2d. "What have you observed as to the effects of caving and of the phenomena attending it?"

Answer. Destructive caving almost invariably occurs at, or immediately below a narrow part of the river, if the river be considerably wider above such narrow part.

In the wide part deposition will occur so long as a lower rate of current exists there. By the loss of deposit at the wide place, the water is in condition to recover from the bed below the quantity lost above, so soon as the velocity is again increased.

The greater value of the river front where cities are built, naturally stimulates the use of artificial means to protect the banks, and to encourage their encroachment upon the channel. The moving of vessels and building of wharves facilitates the process. Much of the refuse matter from cities, and that thrown overboard from vessels, is less easily removed by the current than the river alluvions, and the extension of the bank in such case is more permanent. If the opposite bank be suitably treated, even to a limited degree, an artificial contraction of the width of the stream may be created at a locality where the normal width is quite uniform. In such event I would expect to find the current more sluggish above the contraction and considerable deposition occurring there; while in the contracted portions I would expect to find the channel deepening, and that this deepening would extend some distance below the contraction, for the momentum due to the accelerated velocity would cause the rapid current to be maintained for some considerable distance below it.

If the river were straight in, and for some distance below the contracted part, a deepening sufficient to restore the equilibrium between the scouring and depositing action of the river would probably occur without causing a caving of the banks, as the material removed would be taken up mainly from the middle of the channel, and a considerable deepening could occur without disturbing the angle of rest of the banks. But if a bend existed below the contraction, the caving of the banks in it would occur from a much less amount of erosion; and as soon as the scour had steepened the shore to a greater slope than the angle of rest, and the river had fallen, the caving would begin.

The angle of rest varies with the character of the deposit of which the banks are formed, being lowest where the deposit is of sand, and steepest where it is of clay. The angle of rest also changes with the submergence of the banks by the

rising of the river; for this reason the caving most usually occurs when the river is falling, for the supporting pressure of the water is then withdrawn from them. Hence the visible effect of the erosion may be delayed for months after the scour has ceased. So long, however, as the cause exists the scour will be repeated, and the caving will follow.

I do not presume to assert positively that the caving at New Orleans is caused by such artificial contraction of the river as I have referred to. I do not even know that such contraction exists; I have only suggested it for the purpose of respectfully calling the attention of the Board to the possibility of its being the cause.

Question 3d. "What would you suggest as a temporary and cheap method for preventing caving or retarding it?"

Question 4th. "What would you suggest as a permanent measure?"

Answer. If this general explanation of the phenomena of caving be correct, there are evidently but two remedies, either of which measures will be permanent, if properly applied. The first is to remove the cause, which is the unequal width of the stream; the second and more economic one, is to protect the banks from the scouring effects of the rapid current, by covering them with some material that will prevent any further erosion.

The Board will appreciate the embarrassment under which I am responding to its interrogations, when I repeat the fact that I am absolutely without any data whatever upon the subject; nor is it likely that I can procure any before its adjournment, owing to the irregularities of the mails here.

It is only through deference to the Board and a desire to promote the interests of New Orleans, that I am induced to reply to its questions, even thus briefly, without being furnished with copies of such surveys of the river as are necessary to give me an idea of the form of its bed and banks at, and for some distance above the locality in question, together with the direction of its surface and sub-currents.

No answer other than the general one I have made, can therefore be given to the third and fourth questions, until after such information shall have been supplied.

I have the honor to be, very respectfully,

Your obedient servant,

JAS. B. EADS.

[ALBERT G. BLANCHARD.]

NEW ORLEANS, LA., Nov. 21, 1871.

To the Commission of U. S. Engineers:

Gentlemen—I have the honor to submit a few concise notes in answer to the four questions submitted to me.

Question 1. As to the cause of the caving of the river bank and the destruction of the wharves along the City front.

Answer. By reference to my map of the section of the Artesian Well dug in Canal Street in 1854, the data of which are taken from Humphrey's and Abbott's Report of the Delta Survey, it will be seen that below the vegetable surface stratum of 2 feet thickness, there is a stratum of Blue Clay, 14 feet thick.

On this stratum of Blue Clay all the buildings, levees, etc., on the banks of the Mississippi River have their foundations. Below this stratum are many narrow strata of sand, or sand and clay or shells, down to the depth of 112 feet where a stratum of Dark Drab Clay is reached having a thickness of 34 feet; then below this Dark Drab Clay, for a depth of 53 feet, is found a series of narrow strata of sand or sand mixed with clay, and all the sandy strata are more or less in a liquid state. This brings us to a depth of 196 feet, which is about the lowest depth of the river at New Orleans.

The current of this vast river striking in the bends, on this mass of sand, washes it out from under the clay strata (sometimes to a great distance, acres deep) until the weight of the lower clay stratum is too great to support itself, and a portion breaks off and subsides towards the bottom; then the upper strata sink, and it is well known that acres in depth of land are sometimes sunk, and in high water a crevasse follows.

Question 2. Is answered above.

Question 3. What would you suggest as a temporary and cheap method for preventing caving or retarding it?

Answer. No temporary or cheap method will answer for a contest with this great river, with its depth of 180 feet or more. Cheap and also expensive methods of preventing or retarding the caving of the bank have all failed, because we have only worked at the surface.

We must go down to the bottom of the shelving bank, and face it with such a revetment as will prevent the wash of the current, and yet allow it to move along in its natural course;

any disturbance of the line of the current will only produce eddies or throw it across the river, and cause caving at another point.

Professor Forshey and I have estimated that a revetment of willow mattresses, 150 feet long, well fastened to the bank above high water, and kept down by the pressure of the current and covered with galvanized wire netting could be laid down for $100,000 per mile. But as this estimate may be too low, (as it will require 200 feet width of mattress,) I prefer to estimate the cost of willow mattresses, covered with rip-rap stone, or galvanized wire at $50 per front foot, or in round numbers $260,000 per mile, which is hardly the amount sometimes needed to repair the damages to the wharves and levees caused by the caving bank of the river Mississippi, and which is liable to occur every year.

I am not fixed as to what material to use. Anything that will lay steadily against the bank with a uniform surface, so that the current will not be violently disturbed, will answer. Mattresses will break the current enough to cause a sediment between their interstices, and so will rip-raps, and thus fill up any inequalities of surface below them.

Question 4. Is answered above.

In conclusion. I beg to say to you, and through you to the City of New Orleans and the borderers of the river, *that it will cost more to omit this work, than to carry it out, even at* $500,000 *a mile.*

The river threatens the City with destruction, above at Carrollton, and below in the 2d and 3d Districts.

Let us take warning.

Respectfully,
ALBERT G. BLANCHARD,
Civil Engineer.

[J. A. D'HEMECOURT.]
[L. H. PILIE.]
[L. J. FREMAUX.]

NEW ORLEANS, November 21, 1877.

We herewith transmit our views upon a system of protection of the river bank along the port of New Orleans, left bank, against caves or landslides occurring every year at different points.

The length of the port of New Orleans is simply enormous; it extends from the upper limit of Carrollton to the upper limit of the Crescent City Live Stock Landing and Slaughter House Co.'s property, a distance of nearly thirteen miles. The nature of the banks of the Mississippi river along this line can properly be classed under three different heads, viz: Caving, Washing and Batture Banks. Under these three headings the river front of New Orleans is divided into six sections, as follows:

1st. Caving bank from the upper limit of Carrollton to the lower end of Greenville, about two miles in length.

2d. Batture bank from the lower end of Greenville to near Toledano street, about two and a half miles in length.

3d. From Toledano to Celeste streets, about one mile and a half in length, the bank is generally known as a washing bank, although in this space several caves have occurred almost every year, but are restricted to only a few points, such as Ninth, Sorapuru, Market, and St. Andrew Streets.

4th. Batture bank, from Celeste street to the Morgan's Louisiana and Texas Railroad Landing, about two miles in length.

5th. Caving bank, from Morgan's Louisiana and Texas Railroad to Congress street, one and three-quarter miles in length.

6th. From Congress street to the upper limit of the Crescent City Live Stock Landing and Slaughter House Company's property, about two and one-quarter miles in length, the bank may be termed a washing bank, although several small land slides have occurred opposite the Convent, at the Slaughter House, and a few other places. But these also are restricted to fixed points.

The plan for encasing at once the Mississippi River is not a feasible one, and that for many reasons.

1st. On account of its great depth.

2d. On account of the nature of the soil through which the river flows in Lower Louisiana.

3d. On account of the enormous weight of the alluvion deposit, which would inevitably be made between the breast-work and the land, and which would force out the breast-work, in spite of all the braces that could be placed to retain it to the shore.

The footing for a permanent work cannot be attained quickly, on account of the great depth, which in places exceeds one hun-

dred and fifty feet. To reach that great depth, we must proceed gradually, by lining the edge of the bank with materials that are not susceptible of being washed away by the under currents. Nothing can better serve this purpose than fascines, in connection with crib-work.

To illustrate this system, we will take for example the Sorapuru Cave, and describe the manner of proceeding, which would of course be suited to all other caves

At the low stage of water the whole space of the cave, which is in shape a half circle of one hundred and fifty feet radius, chord three hundred feet, should be dredged to as great a depth as possible; this done, round piles should be planted at every ten feet from centre to centre, in line in each direction; then mattresses, similar in construction to those used by Captain Eads at the South Pass Jetties, that is, composed of thin layers of fascines, laid at right angles to one another, should be sunk into the hole formed by the dredging, and should be superposed until the top mattresses shall have reached the height of the high water mark.

As it is a known fact that piles in cavings have a tendency of leaning outwards, we would recommend that the piles be planted on an inward incline of from fifteen to twenty degrees from the vertical. The piling should also be made secure by means of crib-work, composed of round timber laid both crosswise and longitudinally; two pieces should be used, one on each side of the piles, so as to lock each pile in a square: at each intersection the longitudinal pieces should be made fast to the cross pieces by means of rag-bolts.

The crib-work, thus built, being perfectly independent of the piles, would be at liberty to slide down with the fascines, for the sinking of which ballast can be used. In the space between the high and low water marks, two rows of cribbing should be placed, one at about the centre, and one on top of the last course of matrasses. In this manner, the whole space of the cave shall be filled with a substance much lighter than the alluvion, and not susceptible of being washed away.

This system has the double advantage of securing both a temporary and permanent protection.

Temporary, in as much as it offers a quick protection; and permanent, because when the under current shall have under-

mined the bank at a greater depth than that reached by the first course of mattrasses, and the whole of the facines and crib-work shall have sunk out of sight, and the same process be applied with the exception of the dredging, and that year after year, until the first tier of fascines shall have reached the very bottom of the river, or passed the layer undermined by the current, the bank will present nothing but a substance that cannot be washed away, the protection will have become permanent, and no more caving or landslides will occur. It will require only a few years for the fascines to reach the bottom.

This theory we have drawn from very careful observations made by us for the last thirty-five years, on caving banks where works of the nature above spoken of have been carried on, and which though inadequate to the present wants, have served as a basis for a careful study of the system that we now propose. These observations have been principallv carried on at a caving spot directly opposite the Beef Market.

This point, situated in the middle of the bend of the river, would have long ago been washed away, but for the temporary protection given it at high water by a treble row of ships lying along the wharf. Between these ships and the shore there is hardly any current, so that the water coming there heavily charged with sedimentary matters, deposited a sort of artificial batture which was being continually undermined by the current of the river, at a depth greater than that of the keels of the ships. Now, the water at its high stage, acted as a support to this overhanging batture; but when the water receded, the artificial batture, having no support, went down with it, and so did everything to which the batture was a support, that is, wharves, etc.

At this point the piles, caps, and stringers of the wharves were left in their sunken position, the garbage of the city and ballast have been thrown in the hole, new wharves have been built, and so on, year after year.

In this instance the piles, stringers and caps have played the part of the piles and cribbing that we recommend, and the garbage and ballast, that of mattrasses. So perfect has this been that the point is solidified to such an extent that instead of large landslides, nothing but very slight deflections of the soil occasionally occur.

The wharf alluded to by Mr. Ellermann, at the foot of Hospital street, has been built every year over the old piles, caps and stringers, for over thirty years. The wharf at that point is still sinking yearly, so that taking the slides at six feet per year, the first piles have reached a depth of one hundred and eighty feet. Between this cribbing, as formed by the caps and stringers, and the shore, nothing was put to prevent the undermining as was done in the case at the Beef Market.

The theory of cavings shown above, in the case of the cave at the Beef Market, can be applied to all caves from the Morgan's Louisiana and Texas Rail Road landing to the end of the caving in the Third District.

We can cite only two instances of caves occurring during the high water stage: one on the Lepretre Plantation, on the right bank of the Mississippi, about five miles below New Orleans, and the other also on the right bank of the river, a few miles above the city of Baton Rouge.

It has been observed that in the wharves, the inner piles settle before the outside ones, the reason of this is simple enough. All the battures are formed of deposits of different natures, usually three: coarse sand, fine sand, and light vegetable matters. The coarse sand being the heaviest is the first deposited, the fine sand is deposited nearer in shore, and it is only when the water has become motionless that the vegetable substances which it carries are deposited, and this is very near shore. This vegetable matter is compressible to a great extent, and is sometimes almost liquid, forming a sort of slough with much less consistence than the deposit formed outside.

This last deposit offers the piles a footing much weaker than the deposit of coarse sand, and is the first washed away, carrying down necessarily the piles that are driven into it, while the piles driven in the coarse sand stand much longer. On account of the slough created between the shore and the outside deposit, it is not uncommon to see the inner piles lean outside, and the outer piles lean inside.

J. A. D'HEMECOURT,
City Surveyor.
LOUIS H. PILIE,
Deputy City Surveyor.
L. J. FREMAUX,
Assistant City Surveyor.

[C. G. FORSHEY.]

NEW ORLEANS, LA., Dec. 14, 1877.

To GENL. WEITZEL *and the Hydrographic Commission for the City of New Orleans:*

Gentlemen—Your invitation to me to join the engineers in giving opinion and experience as to the caving of the river front of New Orleans, reached me, in my disabled condition, after the adjournment of your Board. I had supposed myself omitted from the list of engineers addressed.

I shall, however, add my answers to your questions as they occur to me, however late the communication.

The first question is as to the cause of caving in front of the city.

This question may be answered in several parts, as to the localities. I would begin below and treat the front in ascending.

1st. The left bank as far down as the Convent from Elysian Fields street, has been giving way from the year 1848, (?) when a noted cave took place carrying a number of persons with it most unexpectedly. The bank to the depth of 60 or 80 feet and 200 feet ±, more than 100 feet sank suddenly down, giving scarce time to escape. A man on horseback disappeared and never was seen afterward. This was an extreme case; but it has been a caving or crumbling bank ever since. This erosion is chiefly due to *steamboat waves*. The normal abrasion due to current and wind (very slight) tends to encroach slowly upon the bank, as in all concave bends, but abnormal encroachment is due to the accumulation of waves thrown by boats upon this portion of the bank. All the waves of ascending and descending boats, rounding along the whole city front, and the everlasting ferry boats and running tugs, concentrate their waves—both direct and resultant waves—upon this cavity. If those banks were of stone they would wear. But formed of river sand, mingled with only a small portion of clay, they yield against the incessant forces brought against them. Here, more than any other along the city front, these forces are delivered.

This concentration of forces is greatly aggravated by the activity of commerce, and the great docks and marine crafts moved along and sunk on the Algiers front.

2d. The special cause of the extraordinary cave in the lower

part of the bend is properly accounted for by the sudden giving way of a sand pocket, worn into by continual abrasion.

Many such exist, and explain much of the river's caving. The usual phenomena attending such are the sudden sinking down, in low water, from the great weight of the bank, unsupported by the wall of the water.

3d. Ascending to the point of the upper part of the Third and lower half of the Second District, I would assign a totally different cause for the annual sinking of the banks. This, too, has been long experienced, not less than twenty-five years. I attribute the sinking of the banks to the exit of *subterranean springs*. These seem to have their level of discharge at no great depth from the surface of low water, and to discharge themselves with but little energy into the river at low water, and to discharge with them sufficient of the stratum in which they live and act, to cause a subsiding of the bank above. They are evidently suppressed at high water by the counter pressure of the river water. The stratum is evidently thin and soft.

There are several such places in the Mississippi river, notably at Bruslé Landing, a few miles below Baton Rouge, Right Bank. The bank there, where the water rises 30 feet, subsides every year further back, yet never washes away till an area of near 30 acres and more than 500 feet wide has subsided, by slices of only ten, twenty or thirty feet, and only from 6 inches to 2 feet at once. These springs are visible at low water and form a boggy margin. The like would doubtless be manifest in the City of New Orleans, but for the depth at which the springs discharge, ten, twenty or thirty feet below the low water surface.

4th. The caving across the river opposite Poydras, and for half a mile above, I would put in the category of the Esplanade Convent bank, with like causes, charging to the abrasions of steamboat waves, from the energy with which commerce is conducted opposite and above.

5th. Nothing else appears to merit special attention thence till we come to the Carrollton Bend. Here the City is attacked by the river as it is nowhere else, in the 15 miles of its front.

6th. The Carrollton Bend may be described as reaching from Lowerline street in Carrollton to far above the City limits to

Camp Parapet, above the Preston Base of the Delta Survey. And the encroachment on this front may be said to be continual. Its average may be measured by the removal of the levee of 1853, which was 174 feet for near a mile of the distance.

This bank in the fundus of the bend, from Hoey's brick yard to Cambrone street, was originally rivetted by a thick cypress swamp, at least from low water to ten feet above, that bound together by the toughness of the blue clay in which it grew, constituted the most nearly unyielding revetment known to the river, yet it has yielded to the incessant abrasion of the currents and waves at the rate above given. These banks, with the exceptions below, are not *caving banks* properly speaking From Madison street down are *crumbling* banks, gradually worn away by the ceaseless action of currents and waves against banks of loamy river sand and clay, on the concave side. Towards the lower line, from Adams street, the current leaves the left bank and the crumbling is less perceptible.

In 1853, the bank in front of and below Jefferson street, caved into the levee some 20 feet, and caused the authorities to hasten the building of a new levee, which was retired 174 feet. This is believed to be the only *cave proper* in the past 30 years below the Gustine cave of 1872.

In that year, in low water, the Augustine levee, half a mile above Carrollton, suddenly sank to a considerable depth, not less than 30 to 50 feet. The breach in the levee was 300 feet in length and the width of the bank that disappeared was fully 50 feet. This subsidence was manifestly caused by the erosion wearing into a *quick sand pocket*, which at once emptied itself into the current of the river, and was carried away. The limit of this deposit was definitely found. The banks above and below have never given away, except to the regular abrasion of current and waves.

The point of shore opposite has extended down stream and thereby increased and thrown further down in the normal manner the attack upon the left bank.

Having thus examined the whole river front opposite the city, and answered according to the lights that many years study of these banks, and the geology of their constituents, and the observation of their phenomena have thrown upon them, I will proceed to reply to the other queries.

Question 2d. As to the effects of caving and the phenomena attending.

These have been to destroy the wharves and levees and to render it necessary to condemn improved property for levees and streets, or to destroy their value. The phenomena are described in the answer and the description of causes of the caving.

Questions 3d and 4th. In answer to these queries the same reply should be made with proper discrimination, and after a complete survey has exposed the shape of the bottom. No answer is worth much without.

1st. In respect to erosion from natural causes and those due to steamboat waves, and those banks which have suffered from them, I would prescribe thus: Bevel off the front margin of the banks till they will bear a small pile driver 3 to 6 feet. Then clothe the surface of the bottom at right angles to the bank with a netting of galvanized wire, woven in with cane reeds, tops down stream, beginning below and ascending. Make the webs 10 feet ± lapping slightly, and then plant the piles driven home to the anchors, and break off at the ground. Let this kind of work extend out to the angle of 20° (?) in slope of bank.

Near shore on banks that are used for landings, use scantling timber of cypress or clear stuff pine and fascines for mattrasses, and fasten in like manner with piles.

The only difference between "temporary" and "permanent" work will consist in thoroughness and weight of the material, and stone weights to the piles, or substitute them in quantities suited to necessity, on banks not too steep to hold them. This is my method of preventing wear from erosion.

For the banks that sink from subterranean springs, there is no remedy possible where the issue of the springs are out of reach, as is probable in front of the lower half of the 2d District. The subsidence must be looked for and preparations be made to fill up the sunken banks, and this should be with material the least abraseable, that the ordinary wear of the current shall carry them away the least possible.

These banks may be covered with mattrasses as prescribed above. They also will be sunken by the extending stratum below; but structures, wharves, etc., placed in and upon them

may be raised after the subsidence has ceased, and partly be saved.

An experimental bulkhead might be sunk to the greatest possible depth, with the hope of cutting off the stream. They have a source not higher in any case than the highest ground in the city, and would be easily arrested if cut off. The experiment is worth trial, and if successful on a small scale, the bulkhead could be extended to the whole bank affected.

For the caves or sudden sinking of large areas of the bank, like that near the Convent and at the Augustine Levee, (and, indeed, of frequent occurrence on the whole river front, for hundreds of miles above) there is possibly no remedy in human reach.

If it were possible to practice a system of borings near the river front on all banks that are wearing, to discover the deposits of quicksand, we might commence a system of energetic defence of the banks in front to stop the erosion. This will in a great measure be rendered unnecessary by the system of mattresses proposed for the banks in front of the City, that are gradually encroaching.

Hitherto, no encouragement has ever been given to men of knowledge and science to propose expedients or remedies of evils that have from time immemorial menaced the City's safety. In 1849–50, I made a series of 30 ± cross sections and soundings of the river, and again, for Capt. Humphreys in 1851, I made a number of sets; and again 1872–3, I repeated the same sections in precisely the same localities, for the purpose of comparison.

* * * * * * * *

Very respectfully submitted by

CALEB G. FORSHEY,
Civil and Hydrographic Engineer.

TELEGRAMS.

WASHINGTON, D. C., April 3d, 1878.

TO MAJOR WEITZEL, Engineer,

Care of E. Pilsbury, Mayor of New Orleans, La.:

Will you telegraph me the estimated cost of protecting the front of the city of New Orleans and also the necessity for it. and send me by mail the report of your Board on the same.

A. A. HUMPHREYS,
Chief of Engineers.

NEW ORLEANS, April 9th, 1878.

TO GENERAL HUMPHREYS,

Chief Engineer, Washington :

Estimated cost of work recommended by the Board is four hundred and seventy-six thousand dollars. The necessity for doing it is to preserve this harbor, which in imports, domestic exports and foreign exports is the second in the country, and which is the main harbor of the Mississippi valley. The City is utterly unable to do the work.

Report of Board mailed to-day.

WEITZEL,
Engineer.

WASHINGTON, D. C., April 8, 1878.

TO MAJOR WEITZEL, Engineer,

Care of E. Pilsbury, Mayor of New Orleans, La.:

What is the estimated cost of the survey necessary to prepare a plan, and estimate of cost for the protection of the river front of New Orleans, against injurious encroachments of the river?

Answer by telegraph.

A. A. HUMPHREYS,
Chief of Engineers.

NEW ORLEANS, April 9, 1878.

TO GENERAL HUMPHREYS,

Chief Engineer, U. S. Army, Washington :

The cost has been seven thousand, five hundred dollars. Less than one-half of the estimated cost.

WEITZEL.

VARIOUS COMMUNICATIONS.

NEW ORLEANS, Nov. 29, 1877.

Dear Sir—On my return to-day from Port Eads, I find your letter of the 19th inst. awaiting my answer.

Not having made a close examination of the river in front of the City, I can not suggest any definite plan for the protection of its bank in the 2d and 3d Districts, until accurate surveys of the river and observations of its current at high and low water shall have been made.

It is probable that the proper removal of the Point above the ferry landing, at Algiers, to a depth of 20 or 25 feet, would assist greatly in deflecting the current at high water from the caving banks referred to.

I agree with the Board of Engineers in the temporary expedients they recommend to the Hon. Mayor of the City in their preliminary report of the 24th inst.

I remain,
Yours, very truly,
G. T. BEAUREGARD.

To Secretary Board of Engineers.

U. S. S. "ENTERPRISE,"
NEW ORLEANS, LA., Dec. 10, 1877.

Sir—I have the honor to inform you of the arrival last night, at this port, of the U. S. S. "Enterprise," under my command.

The following extract from an order received by me from Rear Admiral S. D. Trenchard, commanding U. S. Naval Force on North Atlantic Station, explains itself.

"On your arrival at New Orleans you will put yourself in communication with the proper authorities of the city, and offer the services of the vessel and the officers for the purpose of making a survey of the Mississippi river, at and about New Orleans, which it is understood the authorities are desirous of having made."

If agreeable and convenient to you, I will give myself the pleasure of calling at 1.30 P. M. to-day, for the purpose of carrying out my instructions.

The bearer of this will await your Honor's reply.

Very Respectfully,
Your obedient servant,
GEO. C. REMEY,
Commander U. S. Navy.

His Honor EDWARD PILSBURY,
Mayor of City of New Orleans, La.

[WM. H. WILLIAMS.]

CITY OF NEW ORLEANS,
Seventh District, late Carrollton,
Nov. 23, 1877.

MESSRS. WEITZEL, BENYAURD AND HOWELL,
United States Engineers, etc.:

Gentlemen—The two portions of the river front of New Or-

leans, most threatened by the caving and abrading character of the banks, are the Second and Third Dsitricts, lying below Jackson Square, and the Seventh District, which lately formed the separate City of Carrollton, and is now annexed to New Orleans.

To the Second and Third Districts, your attention has been specially called, as forming the most prominent object of your investigation. I propose, with your consent, to ask your attention, in this paper, to the condition and wants of the river banks in the Seventh District.

Having been personally and officially familiar, for over twenty-five years, with the river and its banks and levees at Carrollton, it seems appropriate that I should make myself the medium of conveying to you many matters of information, which you may be interested to learn, and which the inhabitants and property owners in this neighborhood feel great interest in bringing to your attention, with the hope that through you, and as a result of your investigations, the authorities of the United States may be disposed to give assistance to the work of river protection here required.

The people of New Orleans and this particular District, would be glad to appeal to the Government for aid in doing a work here which is of the greatest importance to the whole City, as well as to the peculiar locality, but which has been of too great a magnitude to be attempted by the limited means of the late Corporation of Carrollton, and which is still too extensive to be attempted by the great, but greatly embarrassed City in which Carrollton has been absorbed.

The Carrollton shore has always been subject to heavy caving and abrading, and is perhaps the most dangerous part of the river front of New Orleans.

The brief history of the river bank here may be of some interest.

The levee now standing in front of Carrollton, is the third general levee that has been here constructed, and stands about five or six hundred feet in towards the land from what was the original line of water.

The present levee was built in parts, mostly in 1853. The levee next preceding that was built somewhere between 1832 and 1835, twenty years before, and about two hundred feet

further out. And the levee still preceding that of 1835 stood probably about another two hundred feet further out, and with a batture of perhaps of from one to two hundred feet. Thus, the encroachments of the river, from caving and abrasion, amount within the past fifty years, to five or six hundred feet.

The present levee, as you will perceive, if it suits your convenience to make a personal inspection, is approached very closely by the river at many points. In some localities the bottom is very narrow; and at some points, recent caves have cut nearly into the crown of the levee. The necessity for a new levee is threatening. This would be a great misfortune. A new levee, now constructed here, would destroy the whole front of the town (or district), throwing into the river what is now the front or principal street, and destroying a large amount of private property.

This disaster must, nevertheless, follow within a few years, the same to be again repeated, in all probability, after another twenty years, unless something can be done to put an effectual end to the caving and abrasion of the bank.

There appears to be no locality where protective measures against caving and abrading, if any are possible, or where any experimental works for that purpose could be more expedient or appropriate than here. As a citizen of this upper portion of one consolidated city, I would not wish to divert any attention from the lower banks of the 2d and 3d Districts, where the situation and the dangers are about the same, though the encroachments of the river have not been nearly so great; but I would like to remark that we are all now equally a part of the same great City, that improvement and population are traveling upward on the river, and that the building lands of the upper Districts are destined to become very desirable and valuable, if they can be preserved for use by being protected against disasters from the river.

It is presumed, of course, that the survey which you will project and recommend or execute, will include the Carrollton shore, and also the shore for one or two miles above, far enough to embrace the conformation of bank sand currents, by which the Carrollton front is affected. It appears to me that both in the 3d District, and in the 7th District, the survey of the river bottom should be made with peculiar detail and with the greatest

accuracy, for the reason that these are the two localities specially demanding treatment.

For protection against caving and abrasion, there are two projects or modes now engaging attention—the method of warding off the undermining currents of the river from the caving shore, by means of far-reaching jetties, and the method of revetting or carpeting the side of the river bottom with mattrasses.

Neither of these could be adopted without the most careful and detailed survey of the river bed. If jetties should be attempted, they would be of little use unless they project far enough out to cover the outcroppings of the quick-sand beds; from the washing out most caving occurs. If by sounding or diving the position of any such outcroppings can be determined, this would be highly important. If mattrassing should be attempted, that also would be of no use, unless it should be found by a very detailed examination, that the surface to be covered is sufficiently smooth to insure that the covering would be in close contact with the ground. Any irregularities of surface that should prevent mattrassing from lying at any point close on the bottom, would cause under-washing, which would nullify the effect of the revetting, and in time might wash it entirely away.

This minute examination of banks and bottom at particular points, would of course be but a part of the general survey that may be directed.

This general survey, I would consider, should embrace all parts and sections of the river, from perhaps two miles above Carrollton down to the barracks, and perhaps a mile still lower down. It would, I suppose, include a survey of the banks on both sides, with the levees and battures, and a general sounding of the bed on cross-section lines, at suitable distances apart. Immediately in the bends the cross-sections should be numerous and close; on the straight sections of the river, longer intervals would be sufficient.

Much work of this character has been done from time to time, in these upper sections of the river, as well as in the portions in front of the old city, which is from Louisiana Avenue down Whenever records of such previous works are found, it would seem proper that they should be made a part of the records of the new survey now proposed.

But of these general subjects, it has not been so much my object to speak in this communication.

In conclusion, I beg to say, that my chief purpose has been, and is, to invite your attention to the upper sections of the river, with which I have been personally familiar, as a region whose protection is much demanded, and where we hope the Government of the United States may be in some manner induced, by the force of your observations, conclusions and recommendations, to do for our city and our people that which we have not the means of doing ourselves.

As to any preference of plans or projects, I have none to express. That must be left to further investigations. The subject is full of difficulties; and perhaps anything now first done, may be but an experiment. But the necessity is so great that something, it would seem, should be attempted. And if there is any manner in which Government aid can be afforded, we hope that you, being familiar with the situation, may lend your influence and counsel in that direction.

Respectfully communicated,

WM. H. WILLIAMS,

Surveyor and Civil Engineer.

TO THE HYDROGRAPHIC COMMISSION:

Gentlemen—On the Algiers side of the river, opposite McDonoughville, while diving after old sunken material, machinery and boilers, I found many old wrecks, apparently one wreck sunk on top of another wreck, and in every conceivable position, some lying on their beam ends, and down against others lying more level.

These wrecks are the accumulation of years, and form a perfect wall, diverging the current and causing thereby an abrasion of the bank to such an extent, that there is now a deep channel between the wrecks and the bank, leaving the wrecks some distance out in the river, with from 20 to 30 feet of water over them. There is a strong current there nearly all the time.

Wrecks have been accumulating here since long before the war—steamboats of all sizes, both stern-wheel and side-wheel, to avoid expensive wharfage fees, were laid up abreast and some above McDonoughvile from Algiers, and immediately above where the Marine Ways were sunk several years ago.

On many occasions boats thus laid up would catch on fire, burn and sink; frequently when lying close together, three or four boats would burn at a time.

Many of these boats before sinking would get loose, from the burning of their fastenings or moorings, or the pulling out of their stakes or posts, and there being a strong current at all times at this place, it would carry the boats a little down the river and out from the bank before going out of sight and sinking in deep water, where they have accumulated in like manner as in the place heretofore spoken of, further up the river—near where they were originally moored—leaving a space apparently of from one to two hundred feet between the irregular mass of wreck above and those that broke loose and sank further down.

These boats sinking to the bottom and extending diagonally up, and out into the river, several hundred feet from the shore, form an irregular mass which, catching the current, and diverting it in its downward course, throws it against the bottom of the said bank—which is composed of soft sediment produced from the eddy above.

As the bottom portion of the bank washes away, (the work of undermining occupies sometimes several years) the upper portion drops down and slides into the river, carrying everything with it.

A cutting out process evidently takes place on the outside of the old wrecks, for whenever a slide occurs, they are moved by its action still further into the river--the same as the wreck of the Lady Franklin heretofore described.

At this place I have sounded many times, and on many occasions have lost my sounding line, the lead having caught in the old wrecks.

In 1870, I found the wrecks to be in fifty feet of water, whereas to-day there is seventy-five or eighty feet of water over them.

The cutting out process takes place either when the river is rising or at high water, and the caving of the bank generally when the river is low or falling, and the sliding out of the bank on or against the old wrecks, cause them in turn to slide into deep water, or into the channels formed by the cutting out process, the same as in the wreck of the North America.

It is to be remarked that the cavities caused by these slides fill up again in a short space of time, being in the eddy.

The steady deposit of mud upon the wreck of the Steamship General Grant, at high water, I account for as follows:

The Steamship lies on her beam ends quartering down the river, and the water below her weather side, strikes the deck fair, and the starboard bulwarks still remaining on, assist in holding the water, and in preventing the current passing over her weather side from below. Of course this has a tendency to back up the water, and, to a certain extent, momentarily confines it. The friction of the current outside takes away the water so confined, but while confined it lets fall nearly all the large particles of sediment or mud, filling up from below.

The consequence is that a continual settling and filling up of sediment is taking place from below, during the entire stage of high water.

As the water recedes and the river becomes low, the current at this place changes to a variable or softening current, and at low water it forms a strong eddy, about on a line with the deck of the boat, loosening and washing away the sediment deposited here during the strong current in high water.

At the wreck of the North America, the deck being parallel to the bank of the river, the current strikes thereon with nothing to hinder its onward course, and leaves the deck clean without any chance for a settlement to taks place, while at the same time the current driving through the hatchways, scours out the mud deposited during low water.

To prevent further abrasion, and to fill up cavities where a strong current is washing away the bank of a bend in the river, commence at the head of the bend and drive down two piles of large dimensions, the tops if possible inclining towards the bank; then bolt together a crib of timber, composed of old, but sound wharf timber; the crib to be from twenty-five to fifty feet long, and ten feet wide.

Build the crib around the two piles, with a good, strong bottom, the crib to be suspended from the tops of the piles with ropes, and filled with ballast rock sufficient to carry it down and firmly hold it upon the bottom of the river.

When ready, cut the ropes, and the crib will run down to its place, and being held in its position by the piles will there remain until it is properly imbedded by the action of the currents.

Other cribs should then be built at proper intervals along the bend, similar to the one described, save that the first crib should be the strongest; each crib should be about 30 feet high

in deep water, and placed in a position to throw the water towards the channel of the river; the up river end of the crib where the current strikes it should be built flaring.

The object is to form a wall to divert the current towards the channel of the river, without stopping its progress. Of course the current thus diverted will soon be caught by another or outer current, and carried again towards the bank where, it will be again resisted by another crib built lower down, and similar to the one first described; and so on, from crib to crib, until the caving bank is passed.

These cribs may vary in height, with from 25 to 30 feet of water over them at low water, and are made to form a line of protection for the lower portion of a bluff bank. The strong current thus diverted wastes its strength upon the line of cribbing, which forms a splendid breakwater, and protects the bottom of the bank.

Between the cribbing and the bank, and below the top of the cribs, the slackened current lets fall all the large particles of sediment held in solution, which slowly fills up the cavity, and forms after the first year, a hard soil clay bank as high as the protection.

And then where old decayed wharf timber and logs are sunk at the bottom, and half washed out wharf piles are still standing, leaning out towards the channel of the river, catching stumps and debris, heretofore detrimental, will now prove useful in aiding to fill up and strengthen the bank, the sediment falling, covering and uniting all together in one common mass.

Cribs could be built around wharf piles already driven with a beneficial effect, or wharves could be built upon the piles driven to support the cribbing.

After the cribs are properly settled upon the bottom of the river, and no wharf is to be built, the tops of the piles can be sawed off even with the tops of the cribs, so as not to interfere with the shipping.

It is at all times best to have the tops of the cribs incline towards the shore, to prevent scouring out from the bottom. This may easily be done, as the natural inclination of the strong current will be towards the bank.

Should it be necessary to protect the bank above the cribs, willow rafts or mattresses, heretofore described, may be used to

advantage. As unskilled and inexpensive labor can mostly be used, these cribs should only cost from fifty to one hundred dollars each.

A six foot additional base, forming an inclined plane to the heighth of about 6 feet, might be constructed, leaving the bottom of the cribs flaring to receive the current and throw it in an upward direction, thus preventing any possibility of cutting out below, for at all times a current striking an inclined object lifts towards the surface.

The floor beams of the cribs may be of rough logs, placed about 5 feet apart, with dunnage of rough material thrown therein, sufficient to support the stone ballast or rip-rap.

Respectfully,
M. W. FRANCIS,
Submarine Diver and Contractor,
No. 154 St. Joseph Street.

New Orleans, March 4th, 1878.

The charts, maps, drawings and other documents relating to the labors of the Board of Engineers, are on file in the office of the City Surveyor, New Orleans, La.

ROBT. C. WOOD, *Secretary.*